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***APPLICATION***  
***FOR***  
***UNITED STATES LETTERS PATENT***

**Title:** METHOD AND APPARATUS FOR IMPROVING PICK RELIABILITY IN A  
COMPONENT PLACEMENT MACHINE

**Inventor:** Koenraad Gieskes

METHOD FOR IMPROVING PICK RELIABILITY IN A  
COMPONENT PLACEMENT MACHINE

Related Applications:

This application is a Continuation-in-Part of co-pending United States Patent applications Serial Nos. 10/307,848,  
5 filed December 2, 2002 and 09/947,099, filed September 5, 2001. This application is also related to United States Reissued Patent No. RE 35,027, which is hereby incorporated by reference.

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Field of the Invention:

This invention relates to component placement machines and, more particularly, to a method for calibrating vacuum  
15 nozzle positions to ensure accurate and reliable component pick during the machine's placement cycle.

BACKGROUND OF THE INVENTION

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The use of sophisticated component placement machines in manufacturing printed circuit or similar cards, boards,

panels, etc. is well known. The term printed circuit board (PCB) as used herein refers to any such electronic packaging structure. Typically, reels of tape-mounted circuit components are supplied to the placement machine by multiple  
5 feeders, each of which holds a reel of components. A pick station by each feeder assembly provides components. A rotatable frame is equipped with multiple pick/place heads, each having an extendable vacuum spindle that may be moved in the Z-axis (i.e., in and out) between and extended and a  
10 retracted position. The rotatable frame itself is mounted in a housing that may be moved along both the X and Y axes in a plane above a PCB being populated. Each vacuum spindle is equipped with a vacuum nozzle at its tip. The vacuum nozzles are sized and otherwise configured for use with each different  
15 size and style of component to be placed by the machine.

In operation, the housing with the rotatable frame holding the pick/place heads is moved to the pick station and the vacuum nozzle is positioned over a tape-mounted component.  
20 The vacuum spindle is lowered (i.e., extended) to a point where, upon application of vacuum, the component is removed from its backing tape, centered, and held tightly against the vacuum nozzle orifice. The rotatable frame is then moved to a point over the printed circuit board being assembled, the  
25 vacuum spindle is lowered, and the component is deposited on the printed circuit board at a predetermined location.

As component sizes have shrunk, the accuracy of placement of the vacuum nozzle over the component being picked has become more critical. Typically, calibration routines are performed upon machine setup or periodically as required for operation of the machine. However, with micro-miniature components, small variations occurring over time can quickly lead to miss-picks, as well as recognition and orientation problems of these components.

Currently, component placement assembly machines utilize multi-head frames to improve assembly speed. Each frame contains multiple pick/place heads with vacuum spindles, each vacuum spindle having its own vacuum nozzle. With multi-head machines, the need for real-time monitoring of the vacuum nozzle positions becomes even more critical. A vacuum nozzle's position may vary over time due to mechanical binding, build-up of debris, damage to the vacuum nozzle, thermal drift, etc. A changed vacuum nozzle position can be difficult to determine, manifesting its presence only through intermittent pick problems from the various feeders being used to supply the components for placement on the printed circuit boards and through component recognition and orientation errors. If the component itself is misaligned on the PCB, such an error can obviously affect proper operation of other components and larger assemblies.

## SUMMARY OF THE INVENTION

The present invention provides a method whereby each vacuum nozzle position is calibrated during each placement cycle. Any deviation in a vacuum nozzle's position from an expected position may cause pick errors and component rejections that may degrade machine performance and cause defects in the PCBs being populated. The inventive process allows for accurate picking of components, especially very small ones. When the calibration process is applied to a multi-head frame, each vacuum nozzle can be calibrated during each placement cycle. Therefore, the calibration process in multi-head frames causes no slowdown of the placement machine cycle rate (i.e., placement machine throughput).

## BRIEF DESCRIPTION OF THE DRAWINGS

A complete understanding of the present invention may be obtained by reference to the accompanying drawings, when considered in conjunction with the subsequent detailed description, in which:

FIGURE 1 is a side, schematic view of a multi-head frame showing a plurality of pick/place heads having vacuum spindles disposed thereupon;

FIGURE 2 is a simplified schematic diagram of a portion of a component placement machine adapted to practice the method of the invention;

5           FIGURE 3 is a timing diagram of vacuum nozzle image acquisition and processing during the placement cycle time in accordance with the inventive method; and

10           FIGURE 4 is a simplified flow chart of the method of the invention.

#### DESCRIPTION OF THE PREFERRED EMBODIMENT

15           The present invention pertains to calibration of vacuum nozzle positions on the multi-head rotatable frame of a component placement machine used for assembling printed circuit boards.

20           Referring to FIGURE 1, a schematic view of a housing 102 having a multi-pick/place head frame 104 rotatably mounted therein is shown. A plurality of pick/place heads 106 having vacuum spindles 108 are disposed radially around the frame 104. It will be recognized by those skilled in the component  
25           placement machine arts that a frame 104 may carry any number of pick/place heads 106 disposed radially about its perimeter.

For purposes of this disclosure, a general case of n pick/place heads 106 is discussed.

Multi-pick/place head frames 104 are known and the concept forms no part of the present invention. Exemplary multi-pick/place head frames are described in United States Patent No. RE. 35,027 and European Patent No. EP 0 315 799.

FIGURE 2 is a schematic block diagram 200 of a typical image acquisition arrangement for use in a component placement machine. At least one camera 202 is used to capture images, often at different magnifications or with different lighting conditions. The output of the camera 202 is connected to electronic signal processing and control circuitry 210 (i.e., the machine controller). The circuitry 210 controls the camera 202 and provides image capture functions.

The output of electronic signal processing and control circuitry 210 is connected to a vision system 212. It is also known to use a vision system at a process station in component placement machines. Typically, vision systems of the prior art are used to process images of components to facilitate identifying, positioning, and manipulating or orienting the components held against a vacuum nozzle 110 of a vacuum spindle 108. The present invention expands the use of such vision systems 212 to perform calibration of the vacuum nozzle

110 positions during each placement cycle performed by each vacuum nozzle 110 of the component placement machine. The inventive method is operative with any number of pick/place heads 106 and is not considered limited to any particular number thereof. It will also be recognized that the timing data (FIGURE 3) used for purposes of disclosure may vary depending on the actual design of the rotatable frame 104.

In the embodiment chosen for purposes of disclosure, each active vacuum nozzle 110 on each vacuum spindle 108 of each pick/place head 106 on the rotatable frame 104 is imaged during each placement cycle. It will be recognized that in alternate embodiments, other methods including, but not limited to, imaging only a subset of the active vacuum nozzles 110 during a particular placement cycle, and imaging only a particular vacuum nozzle 110 every nth placement cycle could be implemented; therefore, the invention is not limited to the particular sequence chosen for purposes of disclosure.

When a vacuum nozzle 110 is picking up a component 214, its associated vacuum spindle 108 is in an extended position. At calibration time (i.e., when the vacuum nozzle 110 is adjacent the camera 202), the exact position of the vacuum nozzle 110 may be recorded, thereby re-calibrating the position of the vacuum nozzle 110. It is important that the vacuum spindle 108 likewise be in an extended position at

calibration time. This is accomplished by an actuator, not shown, typically affixed to the housing 102, which extends the vacuum spindles 108 as they reach the camera 202. Such an actuator is described in detail in the included-by-reference applications cited hereinabove. It is preferable to calibrate the vacuum nozzles 110 while their associated vacuum spindles 108 are in their extended positions because a vacuum spindle's 108 eccentricity or other factors may cause inaccuracies in the vacuum nozzle calibration data if the calibration process is performed with the vacuum spindles 108 in their retracted position.

The position calibration data is typically placed in a lookup table, not shown, so that the most recent position data may be utilized by the placement machine for the next pick or place cycle involving that particular vacuum nozzle 110. While methods other than lookup tables could be used for storing vacuum nozzle calibration information, a fixed table of vacuum nozzles 110 associated with their position on the rotatable frame 104 has been found to be satisfactory. It will be recognized that other suitable data storage formats could also be used. Utilization of the calibration data by the inventive process is described in more detail hereinbelow.

Referring now to FIGURE 3, a timing diagram for image acquisition and processing within a pick or place cycle is

shown. As may be seen, image acquisition and processing (calibration) for each vacuum nozzle are always completed within a single pick or place cycle.

5           Referring again to FIGURE 2 and also now to FIGURE 4, a flow chart 400 of the steps of the inventive method are shown. It is assumed that initial placement machine setup, vacuum nozzle installation, and calibration have been previously performed. The rotatable frame 104 is moved to a pick station  
10       204, a particular vacuum spindle 108 is lowered, and a component 214 is picked, step 402. This calibration step 406 is repeated for the number of active pick/place heads 106 in the multi-head frame 104 (i.e., each active vacuum nozzle has picked-up a component). It is possible, however, that one or  
15       more pick/place heads 106 may be out of service and therefore may be ignored during any particular pick or place cycle.

          The frame 104 is then moved under program control to the desired X-Y coordinates over the printed circuit board being  
20       assembled at the place station 208. The first vacuum spindle 108 is lowered and the component 214, picked in step 402, is placed onto the printed circuit board, step 404. After component placement begins, the empty vacuum nozzles 110 proceed to the camera 202 where they are recalibrated (i.e.,  
25       their exact location is determined), step 406.

As the components 214 continue to be placed or when the frame 104 returns to the component pick station 204 and the previously calibrated vacuum nozzles 110 begin to acquire new components 214, the remaining vacuum nozzles 110 requiring calibration move to the camera 202. Therefore, during either the placement cycle or the pick cycle, this step is repeated for all vacuum nozzles 110. Details of the vacuum nozzle calibration process, step 406, are provided hereinbelow.

After image acquisition is complete, the image or images are processed, step 406. Processing involves locating the vacuum nozzle position within the acquired image. Assuming that the calibration process, step 406, is able to locate the vacuum nozzle 110 (i.e., the exact position/location of the vacuum nozzle 110 may be ascertained from one or more images from the camera 202), the new position is recorded, step 412, and the placement cycle continues, step 402. If a calibration problem occurs, step 408 (i.e., the exact vacuum nozzle 110 location cannot be determined or the location exceeds a predetermined tolerance range), the operator is alerted, step 410. Depending on the severity of the problem, the component placement machine could be automatically stopped or the pick/place head 106 with the problem vacuum nozzle 110 could be removed from active service until the problem is resolved.

It will be recognized that calibration of a particular vacuum nozzle 110 associated with a particular vacuum spindle 108 need not necessarily be performed. For example, if a vacuum nozzle 110 is not currently in active service, calibration is skipped. It will also be possible to define algorithms for periodically skipping calibration of a vacuum nozzle 110 if placement machine speed places an undue burden on the vision system 212, particularly image processing. Therefore, the invention is not considered limited to a method wherein each vacuum nozzle 110 is calibrated during each placement cycle.

Although the present invention has been described in connection with exemplary embodiments thereof, it will be appreciated by those skilled in the art that additions, deletions, modifications, and substitutions not specifically described may be made without departing from the spirit and scope of the invention as described and defined in the appended claims.

Having thus described the invention, what is desired to be protected by Letters Patent is presented in the subsequently appended claims.